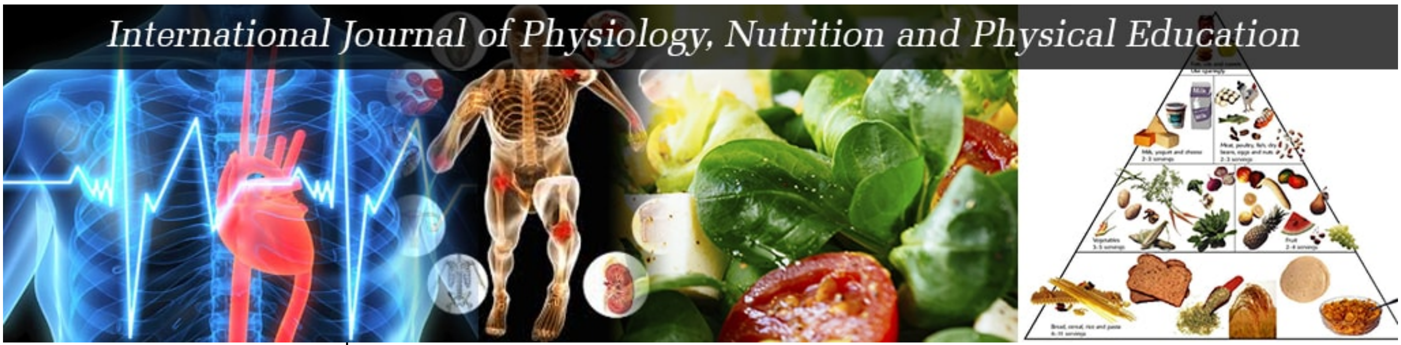

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Impact of psycho-physiological self-regulation on running economy

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Abstract
The aim of the present study was to determine the physiological effects of eliciting the relaxation response during exercise. Nine adult females volunteered to participate in this study. The subjects received 30 minutes of progressive muscle relaxation (PMR) instructions per session for eight sessions. During the week following PMR, the subjects exercised for 30 minutes of continuous activity on the treadmill. The first and third 10 minutes of exercise were control periods. During the second 10 minutes (treatment period), the subjects elicited the relaxation response. Oxygen consumption and related measures were determined using the Beckman Metabolic Measurement Cart. A repeated measures ANOVA was used to analyze the data. During the treatment period, there were significant ($p<0.05$) decreases in Fb, Ve, SBP, and RPP when compared to the two control periods. There were no significant ($p>0.05$) differences in V_t, VO_2, VCO_2, RER, and HR. This study showed that the elicitation of the relaxation response during exercise did not decrease submaximal VO2 and, therefore, did not alter running economy. Statistically significant changes in ventilation and blood pressure were associated with the elicitation of the relaxation response during exercise. Regarding the latter findings, there is ample evidence that a reduction in RPP has a positive and unequivocal beneficial influence on the work of the heart during exercise.

Keywords: Self-regulation, oxygen consumption, ventilation, running economy, blood pressure

Introduction
The purpose of psychophysiologic self-regulation is to learn conscious control of the autonomic nervous system in order to bring involuntary body responses (i.e., respiration, oxygen uptake, heart rate, and blood pressure) under voluntary control. The result may be the learned control to reverse the negative effects of cardiovascular disease, evoke positive body mind-spirit responses to stressors, or to enhance well-being through increased inner peace and calmness. On the other hand, Smith, Gill, Crews, Hopewell, and Morgan reported no significant physiological changes in VO2 and heart rate (HR) when using relaxation during distance running. In agreement, Ashley, Rajab, Timmons, Smith, and Mutrie found that 2 weeks of self instruction in progressive muscular relaxation (PMR) had no significant effects on VO2, HR, and expired ventilation (Ve) during submaximal running. These findings are also consistent with earlier reports by Cadarette *et al*. and Cortes, Boyd, and Boone. The aim of the present study was to determine the physiological effects of eliciting the relaxation response during exercise. Our null hypothesis was that in healthy female subjects the learned self-regulation of the autonomic nervous system at rest would not be under voluntary control during exercise.

Methodology
Nine sedentary adult females (Mean age = 23±2 years; Mean mass = 59±2.9 kg; Men height = 164.2±0.8 cm) volunteered to participate in this study. None of the subjects was engaged in a regular exercise program or relaxation training prior to the experiment. The subjects gave their informed consent, and were informed of the test procedures and purpose of the study.

Experimental procedure
During the orientation day, the subjects were given verbal instructions and familiarization with a progressive muscle relaxation (PMR) strategy designed to elicit parasympathetic dominance. This strategy required the subjects (under the direction of the instructor) to consciously tense

and relax major muscle groups throughout the body to become more aware of subtle degrees of tension. The subjects received 30 minutes of PMR instructions per session for eight sessions (using a Monday, Wednesday, and Friday schedule). Heart rate, systolic blood pressure (SBP), and rate pressure product (RPP) were recorded at scheduled intervals to validate the PMR strategy. The PMR sessions resulted in significant ($p<.05$) decreases in HR (74±9 to 63±8 beats/min), SBP (122±10 to 110±12 mm Hg), and RPP (90±6 to 69±8), respectively from the first PMR session to the eighth PMR session.

Physiological measures

Frequency of breaths (Fb), tidal volume (Vt), expired ventilation (Ve), VO2, carbon dioxide production (VCO2), and respiratory exchange ratio (RER) were determined by the Beckman Metabolic Measurement Cart (MMC), which was calibrated prior to and checked after each test session with standardized reference gases. Heart rate was determined by 10-second electrocardiographic strips using a modified CM5 lead. Only the values during the second 5 minutes of each 10-minute period were averaged and statistically compared. Systolic blood pressure was determined indirectly during minutes 10, 20, and 30 by auscultation of the left brachial artery using a standard sphygmomanometer.

Statistical analysis

To verify that the subjects were able to elicit the relaxation response following the eight PMR sessions, physiological data from the first and eighth sessions were statistically compared using a two-tailed paired ttest. An analysis of variance with repeated measures was used to assess the mean difference for each variable across the three 10-minute exercise periods. Where indicated, a Newman Kuels post hoc analysis was used to determine the significant differences among the means. An alpha of 0.05 probability level was used for all tests of statistical significance.

Results

Means and standard deviations were computed for all physiological data (Table 1). Statistical analysis indicated significant differences ($p<0.05$) in the Treatment values for Fb, Ve, SBP, and RPP versus Control I and/or II. There were no significant differences ($p>0.05$) in V_t, VO_2, VCO_2, RER, and HR.

Table 1: Cardiorespiratory and Hemodynamic Responses at a Fixed Work Intensity Before (Control I), During (Treatment), and after (Control II) the Subjects were Told to Try and Elicit the Relaxation Response (M±SD)

Variable	Control I (A)	Treatment (B)	Control II (C)	F-ratio & Prob
Fb breaths/min	31 ± 8 A-B**	28 ± 7	30 ± 8	5.68 & .01*
Vt ml/breath	784 ± 95	814 ± 115	797 ± 104	1.63 & .22
Ve l/min	24 ± 3 A-B** A-C**	23 ± 3	23 ± 3	6.06 & .01*
VO_2 l/min	.79 ± .06	.78 ± .05	.77 ± .05	2.15 & .14
VCO_2 l/min	.67 ± .07	.66 ± .07	.65 ± .06	1.91 & .18
RER	.85 ± .04	.85 ± .04	.84 ± .05	.25 & .78
HR beats/min	125 ± 13	122 ± 9	122 ± 15	3.00 & .07
SBP mmHg	132 ± 13 A-B**	124 ± 9 B-C**	132 ± 12	4.08 &. 03*

(Contd.)...

**Newman Kuels post hoc analysis ($p<0.05$)

Discussion

The major finding of this study was that the elicitation of the relaxation response during submaximal treadmill exercise did not result in a significant decrease in VO_2. The null hypothesis was supported. The subjects were not able to improve their running economy (i.e., decrease VO_2) during the exercise period in which psychophysiologic self-regulation was practiced Although the mechanisms involved in producing a decrease or no change in VO_2 remain unclear and invite further investigation, several reasons might explain this finding.

First, there is much still unknown regarding the proposed integrated hypothalamic response that is hypothesized to be the relaxation response. In particular, the suggestion that relaxation training and meditative practices (including most other bio-behavioral interventions such as imagery, biofeedback, and music) result in a decrease in VO_2 at rest and during exercise is simply not correct. This is evident with the preceding discussion that illustrates the equivocal results in the literature. Also, the case reports study by Benson, Malhorta, Goldman, Jacobs, and Hopkins in which VO_2 increased during advanced meditation illustrate this point. Second, there is the unanswered question regarding the subjects' difficulty in eliciting the relaxation response during exercise.

The decrease in SBP suggests an improved efficiency of the central circulatory system as evident by the significant decrease in RPP, which is an established correlate of cardiac work and myocardial oxygen demand. This finding is particularly important given that exercise HR did not decrease during the elicitation of the relaxation response, and that it appears to contradict the notion that PMR training results in a parasympathetic response. Clearly, in the present study, the SBP response was the primary parasympathetic measure and, as a component of the RPP calculation, the primary method by which the work of the heart was reduced at the fixed work load which illuminates an important point.

Conclusions

Given the fact that no change in VO_2 occurred during the exercise period in which the relaxation response was elicited indicates the imperturbability of the subjects' exercise metabolism and thus unchanged running economy as presently defined. It is very tempting to, therefore, question VO_2 as the criterion variable for demonstrating changes in running economy. The results of this study reinforce rather the importance of psychophysiologic self-regulation during exercise on respiratory and myocardial variables (particularly F_b, V_e, and RPP). Regarding the latter variable, there is ample evidence that a reduction in RPP has a positive and unequivocal beneficial influence on the work of the heart. This consideration alone may be of more practical significance than the measured VO_2 and, theoretically, may enable the performer to better tolerate the central demand associated with exercise. Based on this interpretation, not unexpectedly then, the net result is a better performance.

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